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WE REGRET that, owing to the printing dispute, publication of this issue is unavoidably delayed. It is possible that the Autumn issue may be similarly affected.

The Oat Crop

D. J. GRIFFITHS

Welsh Plant Breeding Station, Aberystwyth

ONCE MORE the peace-time pattern of cereal production in England and Wales is gradually taking shape. One of the features of this pattern is the substantial change-over from spring oats to barley growing which has taken place during the last ten to fifteen years.

With improvements in food supplies from abroad, a general fall from the war-time years of peak production was to be expected in the acreages of cereals intended primarily for livestock feed. Nevertheless, it was not known to what extent the introduction of mechanical power for harvesting, etc., more extensive use of fertilizers, availability of vastly improved varieties and modifications of cropping systems would affect the relative importance of the three leading cereals in the present-day economy of farming.

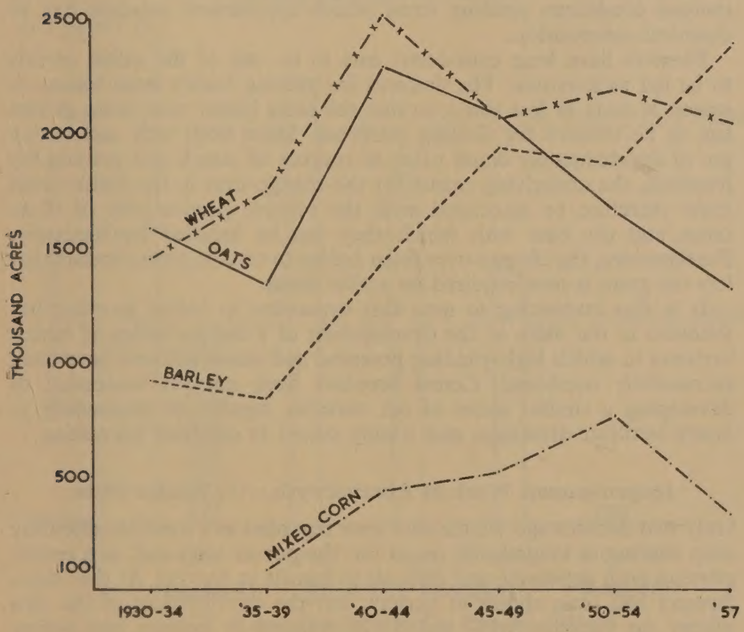

FIG. 1. Cereal acreages in England and Wales, 1930-57.

Examination of the acreages devoted to wheat, barley and oats since 1930 (reproduced graphically in Fig. 1 overleaf) clearly shows a marked change in the crop picture: when such figures are considered on a regional basis it will be observed that this replacement of oats with barley has taken place chiefly in arable areas, whereas in the cooler and more humid regions, where cereal cropping is almost entirely restricted to the needs of livestock on individual farms, the proportion of oats to other cereals has remained substantially the same.

In such regions the crop is grown for both its grain and straw, the latter being considered greatly superior to wheat straw in feeding value and also better than that of barley. Indeed, the importance of this dual-purpose nature of the crop cannot be over-emphasized, and the high value of oat straw as fodder for cattle in winter is one of the major factors which determines the large acreage grown in localities considered less favourable to grain production. In this context, the recent work published by Dent [3] on the quality of oat straw is of extreme importance. Although he found little or no difference in the straw of various varieties grown under similar conditions, differences attributable to environment were very large, with crude protein values ranging from 1.7 to 7.6 per cent, with crops grown under the cooler, moister conditions yielding straw which approached meadow hay in chemical composition.

Farmers have long considered oats to be one of the safest cereals to be fed to livestock. The demand for malting barley from season to season is more or less static, so that the extra barley now being grown has to be utilized for feeding purposes. Since both oats and barley are of approximately equal value as sources of starch and protein for livestock, the underlying causes for the change-over in the arable areas must therefore be associated with the relative productivity of these crops and the ease with which they can be handled mechanically. Furthermore, the change-over from horses to tractor power means that less oat grain is now required on arable farms.

It is also interesting to note that expansion in barley growing has followed in the wake of the development of a unique series of barley varieties in which high-yielding potential and straw stiffness have been successfully combined. Cereal breeders have not yet succeeded in developing a similar series of oat varieties capable of responding to heavy fertilizer dressings, and wholly suited to combine harvesting.

Improvement Work at Aberystwyth : (1) Winter Oats

Only two decades ago winter oats were regarded as a most troublesome crop tending to lodge badly on all but the poorer soils and, as a result, proving both expensive and difficult to handle at harvest. At that time, farmers had little choice of variety, but the development of the two winter oat varieties S.147 and S.172 released to farmers just before World War II has created a new interest in the crop. Experience

with these varieties on an increasingly wide scale soon showed the need for an additional variety intermediate in straw length between these two, and possessing the good grain characteristics of S.147. This objective, initiated in 1940 by crossing S.172 and S.147, was partly fulfilled by the new variety Powys (S.226), released in 1956. It is shorter and stiffer in the straw than S.147, earlier ripening than either of its parents, and intermediate in its panicle and grain characters.

The main limitation to further expansion of the winter oat crop is that none of the existing varieties possesses the high expression of winter hardiness exhibited by either winter wheat or winter barley. Improvements in this important varietal characteristic would extend the area now regarded as reasonably safe for winter oat cultivation and would lessen the risk of losing crops during hard winters such as those experienced during 1953-54 and 1955-56.

Hybrid progenies of crosses involving S.147 and certain mildew-resistant spring selections as parents, have given rise to lines of decidedly superior hardiness to their winter parent (Fig. 2), and an extensive search for improved hardiness amongst progenies of various crossing combinations of this type is now being undertaken.

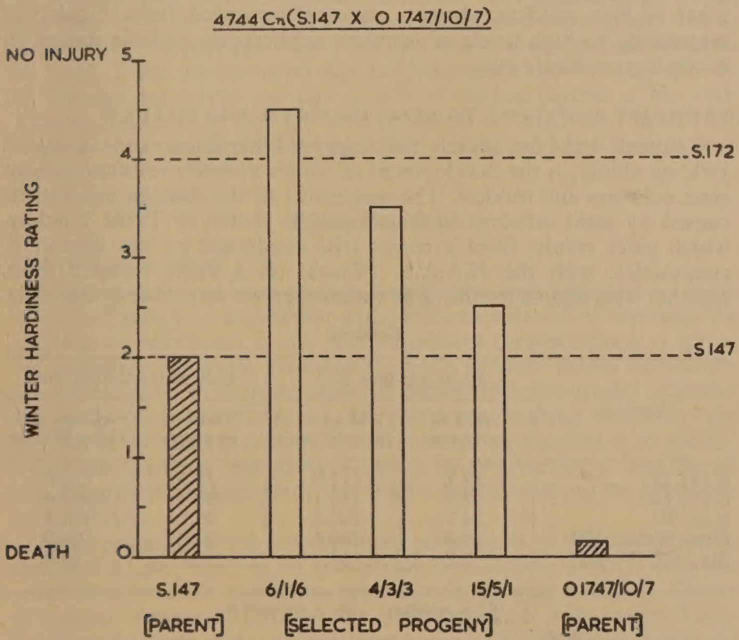

FIG. 2. Winter Hardiness in Oat Crosses, 1955-56.
(4744 Cn (S.147 × O1747/10/7)).

such as Sun II and Blenda must be regarded as general purpose varieties for conditions of only moderate fertility.

Plant breeders have attempted to solve the problem for high fertility conditions by breeding and selecting varieties with a reduced capacity for straw production and a high ratio of grain to straw. The first of this kind is Milford (S.225), which can be grown with less risk of lodging than any other spring-sown oats. Current research is concerned with improving the yielding potential of these short-strawed types, increasing the grain size and selecting for a less compact head.

THE PROBLEM OF THE UPLAND FARM WITH POOR SOIL

When considering types for inherent soil poverty coupled with all the adversities of an upland climate, the breeder is confronted with a totally different set of problems. It is mainly in these situations that the older straw-producing "land" varieties continue to be grown because of their capacity to produce a good bulk of fodder under conditions where most of the newer large-grained varieties have given disappointing results. With improved cultivations, earlier sowing, and better manuring, these low-yielding varieties could with advantage be replaced by Maldwyn (S.221) which has shown its superiority over a wide range of conditions of average and below-average cropping potential.

Present-day costs of production are extremely high, especially for the upland farmer who, on account of poor harvesting conditions, has to buy new seed each season and be content with less return in terms of yield per acre. The importance of using good seed in the uplands cannot be over-emphasized; losses of as much as 25 per cent in yield of grain through using "once-grown" seed are reported by Jones [5] from experiments carried out to compare the yielding performance of crops grown from "new" and "once-grown" seed under poor upland conditions. More recently, a series of varieties grown and harvested in different localities have also shown similar location effects when brought back to the Station's trial grounds for yield testing.

BREEDING FOR RESISTANCE TO DISEASE

When breeding for better yields, increases may be sought either by direct improvement of what may be termed yield characters, or by removing or reducing the effect of some single factor or factor complexes which limit yield. As improvements have taken place in field characters such as straw strength and yielding ability, weaknesses such as disease susceptibility—hitherto regarded as of minor importance—have become more serious limiting factors. Furthermore, the increased use of fertilizers, especially nitrogen, has tended to favour the incidence of diseases like powdery mildew.

Progress has been made in the development of desirable agronomic types possessing resistance to both crown rust and mildew, and the value of mildew resistance is clearly demonstrated in Table 3, which

gives the results obtained from yield trials carried out in recent years and a comparison with susceptible controls.

Table 3
Mean Yield of Grain obtained from Mildew-resistant and Susceptible Oat Selections, 1953 and 1954

Variety or Selection	Reaction to Mildew	Grain Yield 1953 Slight Mildew Attack	Grain Yield 1954 Heavy Mildew Attack
		cwt/acre	*cwt/acre*
Sun II . . .	Susceptible	26.9	21.8
S.84 . . .	„	27.9	18.7
4757/6/2/19 . .	Resistant	29.2	30.5
4757/18/2/19 . .	„	30.1	29.2
Sig. Diff. (P=0.05)		3.93 (n.s.)	3.43

The above results not only show the superiority of the resistant selections over susceptible varieties under heavy disease conditions, but also provide an indirect measure of the losses which can be incurred from a serious attack of mildew. Similar estimates of crop loss have been obtained from spraying experiments, but breeding is the best approach towards control of mildew for it obviates costly spraying operations. It is encouraging to note from Table 3 that the mildew-resistant types are also capable of good yields in disease-free seasons, and both selections have the added virtue of being resistant to crown rust, a disease which causes trouble in Devon and Cornwall in certain seasons.

Another important feature of mildew-resistant selections is their marked superiority in lodging resistance when the crop approaches maturity. After a heavy mildew attack various saprophytic fungi are able to establish themselves on the maturing straw of susceptible varieties making it extremely brittle. As a result, harvesting is difficult and the straw of little use for feeding. Mildew-resistant types, on the other hand, are far less affected by these secondary infections, and in consequence the straw retains its resilience and capacity to support the grain crop until fully ripe.

THE FRIT FLY MENACE

Undoubtedly, one of the major pests of the spring-sown oat crop is the frit fly, especially in areas having dry weather in the early months of the year. Investigators have reported a moderate degree of resistance to frit fly attack in the seedling stage in the varieties Summer, Spet, Hede, von Lochow's Yellow and Eagle, when tested in small plots.

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Bingham and Lupton [2], however, consider that these varietal differences in susceptibility are due principally to escape because of the fly's preference for certain varieties when egg laying, although in some instances a degree of tolerance could be related to tillering capacity. Their observations on panicle attack also showed that the percentage of infection is again largely dependent on the stage of development of the plants at the time of egg laying, although there were indications that von Lochow's Yellow did possess a "measure of heritable resistance to the panicle attack". However, in order to achieve freedom from the pest, genotypes possessing a much higher degree of resistance to both tiller and panicle stages of attack are required, and until these are forthcoming the farmer must endeavour to avoid the pest by sowing as early as possible.

EELWORM PROBLEMS

Damage to the spring crop by stem eelworm is less severe than in winter oats, although reports of losses to the former appear to be on the increase especially in the north of England [6]. Spring-sown varieties make quicker and more immediate growth, and are thus able to grow away before the eelworms establish themselves in sufficiently large numbers to gain ascendancy over the plants. Through the use of the backcross technique the Grey Winter type of resistance is now being bred into the leading commercial varieties as well as into the new Station selections which already possess resistance to both mildew and crown rust.

Cereal root eelworm caused by *Heterodera major* is a widely distributed pest attacking all the temperate cereals, but it is most serious on oat crops grown on lighter soils in poor heart. The other cereals may carry large numbers of cysts in their roots but their growth is less affected. An extensive search amongst the more commonly cultivated British and European varieties has failed to reveal any indication of complete resistance to this parasite, but recently Andersen in Denmark [1] has reported the discovery of good resistance in *Avena sterilis*. Meanwhile, however, until we establish that this species carries resistance to the biologic forms which exist in Britain, and until this resistance is bred into our economically-adapted varieties, oat cropping should be avoided on infested soils. Unfortunately, cysts may be found in practically all the commonly used economic grasses so that grassing down the fields does not provide complete control.

Conclusion

From this review of some of the field problems associated with the crop, and of the attempts made to solve some through breeding, it is apparent that both variety and husbandry are of paramount importance for the production of better oat crops in all the diverse situations where they are grown. Whilst the right choice of variety is all-important,

maximum yields can only be secured by paying attention to cultural details and manuring. The importance of sowing spring oats as soon as a suitable dry seed bed can be prepared cannot be over-emphasized, for there is a close association between earliness of sowing and high yield of grain. At best, a spring-sown crop, like spring barley, is only in the ground for about five-and-a-half months, and any delays in sowing, or setbacks during the growing period, are bound to hamper development in some way or another. Disease resistance is considered an added insurance against depleted yields in seasons when disease epidemics occur, or when the crops are grown in pest-infested soils.

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Some Observations on Soil Development on Restored Opencast Coal Sites

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SINCE 1940, the restoration of opencast coal sites has presented many problems which have been described by several authors [1, 2, 3 and 4].

During removal, storage and subsequent restoration, the original soils undergo profound physical, chemical and biological changes. Hunter and Currie [5] have pointed out the physical deterioration of certain heavier soils in Northumberland. Hunter [6] has also reviewed the problems of fertilizer requirements and biological activity. The present article is concerned with certain pedological phenomena and associated effects.

The observations were made at two experimental centres; one in Northumberland at Milkhope [5] where the soil, before removal, was developed upon a heavy glacial drift of fairly high base status, and the other at Cole Pike in Co. Durham where previously the soil had a medium texture and a lower base status.

The experiments were designed to study the effects of applying various amounts of superphosphate to grassland on newly restored land. At each centre two identical experiments were established, one under controlled grazing, the other cut for hay. The sites at Milkhope and Cole Pike were sown to grass in August 1953 and August 1954 respectively, after which dates the treatments of haying and grazing commenced. Both sites had an initial dressing of waste lime at the rate of 4 tons per acre, which would contain as an impurity approximately 1 cwt of sulphate of ammonia per acre. It is worth noting that whilst the Milkhope Site responded significantly to superphosphate treatments, there was no marked effect at Cole Pike. The indicated difference in soil phosphate status has since been confirmed by soil analyses.

A Comparison between "Hayed" and "Grazed" Sites

The significance of this article lies in the fact that although the soil profiles considered are within the experimental areas, the actual profile sites described and illustrated are situated in the centre of the pathways between the blocks where no fertilizer has been applied other than the original waste lime. Thus the only difference in treatment of the soil profile sites is whether the herbage is cut for hay or grazed. A point to be borne in mind is that, to a small extent, the profiles on the grazed plots will have received excrement from the grazing animals.

Table 1

Botanical Analyses of Experimental Areas

(*Mean Percentage Values*)

Species	Milkhope (1955) Seeded August 1953		Cole Pike (1956) Seeded August 1954	
	Hayed	Grazed	Hayed	Grazed
Per. Ryegrass	34.2	55.1	11.6	44.7
Cocksfoot	24.9	15.4	13.1	5.6
W. W. Clover	0.6	6.7	3.0	14.3
Red Clover	2.8	4.8	0.9	0.6
Timothy	6.8	7.9	21.6	8.5
Meadow Grass	—	—	0.4	8.2
Agrostis	—	—	—	3.1
Weed	—	—	—	0.1
Bare ground	30.6	10.3	49.1	14.7

Note: The bare ground is being colonized by mosses.

The grazed and hayed plots showed distinct differences both in sward composition (see Table 1 above) and in underfoot "feel". For these reasons the following profiles were dug and examined.

Soil Profile Descriptions

(*Figures in parentheses show colour recorded by Munsell Colour Charts.*)

MILKHOPE	COLE PIKE
Date: 8.10.57. *Height:* 230 ft *Grid Ref:* NZ/215.754 *Parent Material:* Glacial drift from N.E. *Relief:* Drift-covered plain *Aspect:* Westerly. *Rainfall:* 25 in.	*Date:* 9.10.57. *Height:* 600 ft *Grid Ref:* NZ/146.457 *Parent Material:* Glacial drift of local origin *Relief:* Strongly rolling due to deep river incision *Aspect:* Southerly. *Rainfall:* 30 in.
Hayed *Vegetation:* Tussocky Cockle Park mixture (some mosses)	**Hayed** *Vegetation:* Well-developed Cockle Park mixture, tussocky
0-3 in. greyish brown (10 YR 4/1.5) stoneless heavy loam. Structure: compound fine sub-angular blocky with frequent faunal casts, surface almost covered by faunal material. Readily permeable and numerous small cracks and fissures. Horizon extremely friable and riddled with large and small living roots. Clover nodulation very apparent. Faint traces of fine rusty mottling (5 YR 5/8) along some very fine old root channels. This horizon merges irregularly into	0-2 in. dull greyish-brown loam (10 YR 3/2) with occasional stones. Structure: medium to fine sub-angular blocky containing many worm casts. Soil very friable with high degree of permeability. Numerous earthworms with casts throughout horizon to surface, micro-faunal activity apparent. Roots very numerous everywhere both coarse and fine. Faint traces of rusty mottling found in old root channels (5 YR 5/8). This horizon merges irregularly into
3-13 in. greyish-brown clay loam (10 YR 4/3) with occasional stones. Major structure faces have grey patches (10 YR 6/1) with rusty mottling near top (5 YR 6/8) changing to rusty blotching at depth (2.5 YR 4/8). Horizon characterized by weak to moderate development of prismatic structure with zone 3-5 in. angular to sub-angular blocky structured, only weakly	2-10 in. dull greyish-brown loam (10 YR 3.5/2) containing some small stones. Angular blocky structure well-defined. Large amounts of worm-cast material throughout. Some slight gleying of structure faces but horizon very friable and readily permeable with some pores in peds. Roots numerous throughout, passing through matrix as readily as along structure faces. Clover

SOIL PROFILE DESCRIPTIONS—(*continued*)

(*Figures in parentheses show colour recorded by Munsell Colour Charts.*)

MILKHOPE	COLE PIKE
Date: 8.10.57. *Height:* 230 ft *Grid Ref:* NZ/215.754 *Parent Material:* Glacial drift from N.E. *Relief:* Drift-covered plain *Aspect:* Westerly. *Rainfall:* 25 in.	*Date:* 9.10.57. *Height:* 600 ft *Grid Ref:* NZ/146.457 *Parent Material:* Glacial drift of local origin *Relief:* Strongly rolling due to deep river incision *Aspect:* Southerly. *Rainfall:* 30 in.
Hayed *Vegetation:* Tussocky Cockle Park mixture (some mosses)	**Hayed** *Vegetation:* Well-developed Cockle Park mixture, tussocky
3-13 in. (*contd.*) joined into prisms. All horizon very friable and permeable, some pores found. With depth, prismatic tendency strengthens but soil remains moderately friable. Worms active throughout horizon and casts frequent. Strong roots abound, slightly more on structure faces than in matrix. Clover nodulation pronounced almost to depth irrespective of structure face or matrix.	2-10 in. (*contd.*) nodulation very strong and noticeable throughout. Fine rusty mottling occasionally found (5 YR 5/8) chiefly related to old root channels. Some added $CaCO_3$ seen (residual from initial application of waste lime). Earthworms very frequent. Evidence of much micro-faunal activity.
13 in. + at this depth sharp change to "overburden" with little or no profile development. Very variable in texture and laminated due to replacement. Very faint tendency to weak prismatic structure. Some stronger roots penetrate but no fauna. Strong gleying observed at top of horizon and between laminations.	10 in. + at this depth sharp and irregular change to replaced overburden which is fairly well laminated but penetrated occasionally by strong vertical cracks. Roots found in this closely consolidated material where texture little lighter. Earthworms penetrate to small degree but casting concentrated on top of horizon. Strong gleying taking place between laminations. Tendency for rusty mottling (5 YR 5/8) continue upwards into horizon above for less than ½ in.

Characteristics Common to Both "Hayed" Profiles

1. No artificial drainage on either plot.
2. No surface "mat" of undecomposed organic litter.
3. Ready permeability of water due to good structure development.
4. Good rooting systems limited only in depth by closely compacted overburden.
5. Build up of soil fauna is good.
6. Gleying, due to water perching, is confined to base of replaced topsoil but mostly in the top of the overburden.

SOIL PROFILE DESCRIPTIONS—(*continued*)

(*Figures in parentheses show colour recorded by Munsell Colour Charts.*)

MILKHOPE

Date: 8.10.57. *Height:* 230 ft
Grid Ref: NZ/215.754
Parent Material: Glacial drift from N.E.
Relief: Drift-covered plain

Aspect: Westerly. *Rainfall:* 25 in.

Grazed

Vegetation: Closely-knit Cockle Park type sward with small bare patches being rapidly colonized by mosses

½-0 in.
black, partially decomposed organic layer with grass surface roots visible in bare patches. Horizon closely compacted with clear boundary below.

0-3 in.
dull greyish-brown heavy loam (10 YR 3.5/2) containing very few small stones. Compound sub-angular blocky structure moderately well-developed; numerous living and dead roots chiefly confined to structure faces. Matrix shows few pores but is fairly permeable and friable. Few earthworms, little evidence of soil faunal activity. Some rusty root

COLE PIKE

Date: 9.10.57. *Height:* 600 ft
Grid Ref: NZ/146.457
Parent Material: Glacial drift of local origin
Relief: Strongly rolling due to deep river incision
Aspect: Southerly. *Rainfall:* 30 in.

Grazed

Vegetation: Fairly close-knit Cockle Park type sward with mosses encroaching

½-0 in.
black sporadic layer of organic matter with very small amount of decomposition at base. Closely compact with very strongly developed fine root mat.

0-1½ in.
dull grey-brown (10 YR 3.5/2) stoneless loam. Structure: medium to fine angular to sub-angular blocky, weakly friable. Some evidence of micro-faunal activity visible as very small round aggregates. Whole horizon closely bound by very high root concentration, living and dead, with fine rusty mottling (2.5 YR 4/6) visible along roots and root channels. Very few small stones, and whole horizon closely compacted, hence

SOIL PROFILE DESCRIPTIONS—(*continued*)

(Figures in parentheses show colour recorded by Munsell Colour Charts.

MILKHOPE	COLE PIKE
Date: 8.10.57. *Height:* 230 ft *Grid Ref:* NZ/215.754 *Parent Material:* Glacial drift from N.E. *Relief:* Drift-covered plain *Aspect:* Westerly. *Rainfall:* 25 in.	*Date:* 9.10.57. *Height:* 600 ft *Grid Ref:* NZ/146.457 *Parent Material:* Glacial drift of local origin *Relief:* Strongly rolling due to deep river incision *Aspect:* Southerly. *Rainfall:* 30 in.
Grazed *Vegetation:* Closely-knit Cockle Park type sward with small bare patches being rapidly colonized by mosses	**Grazed** *Vegetation:* Fairly close-knit Cockle Park type sward with mosses encroaching
0-3 in. (*contd.*) mottling (5 YR 6/8) found in the blocks. This horizon merges irregularly into 3-13 in. grey-brown heavy loam (10 YR 4/2) with strong rusty mottling (7.6 YR 5/6). Strong prismatic structure dominates horizon. Prisms impervious but some percolation down structural faces. Few strong roots found, confined to upper 3-4 in. At base of horizon prisms much duller and greyer (10 YR 6/1.5) and roots rare. Horizon closely compacted. Compaction increases with depth where suggestion of laminated structure can be seen (probably due to machinery). Coarse rusty mottling (5 YR 5/8) and manganese blotching very strong at base of horizon which merges irregularly with 13 in. + laminated overburden. Little or no pedological development. Infrequent roots penetrate to run along the laminations.	0-1 ½in. (*contd.*) permeability very poor. Some original waste lime still discernible. This horizon merges irregularly into 1½-11 in. dark greyish-brown (10 YR 3/1.6) stony loam with ochreous mottling (2.5 YR 4.5/8). Strong prismatic structure dominates horizon; very few pores found. Top of prism very strong but structure weakens with depth, with tendency to coarse angular blocky form. Numerous roots found on main structure faces, about half of them alive, and clover nodulation disappears at 7 in. Odd pockets of waste lime. Very strong ochreous mottling confined to old root channels through prisms and down structure faces. No faunal activity apparent; small amount of gleying on structure faces. 11 in. + general overburden very strongly compacted (machinery) and laminated due to replacement. Very occasionally roots go down rare vertical cracks and penetrate laminations.

Characteristics Common to Both "Grazed" Profiles

1. No artificial drainage on either plot.
2. Litter accumulation on surface.
3. Close compaction below surface due to treading animals.
4. Poorly-developed root systems which cannot penetrate the tightly packed soil.
5. Lack of earthworms and general faunal activity.

Conclusions

From the above profile descriptions, similarities between the "hayed" soils at both centres and likewise between the "grazed" soils can be seen. Conversely, substantial differences between "hayed" and "grazed" profiles at each centre are very apparent. Although there is a variation in the phosphate status of the restored soils between the two experimental centres it appears that the treatments of haying and grazing are responsible for the differences in the soil profiles developed. From this one can argue that the chief causal factor would appear to be the grazing animal. It seems that shallow poaching and compaction of the restored topsoil by hooves have a harmful effect. On the other hand, haying carried out over a short period in dry conditions causes little or no damage to the grass and soil. Further, although it is recognized that continuous haying depresses clovers and coarsens the sward there is still an appreciable hay yield with satisfactory management. Under continuous haying one can infer from the above descriptions that the soil structure and related features, e.g., increase of soil fauna and organic matter, will continue to improve. The soil must be restored in the fullest sense of the word, even though it may prove to be a long-term policy. It is, of course, recognized that there are practical difficulties which may be encountered by adopting such a policy.

We wish to thank Dr. K. Shaw for his helpful comments and Mr. H. Mead from whose botanical analyses Table 1 was compiled.

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Fluorescent Tracers in Insecticide Sprays and Dusts

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FOR some considerable time it has been realized that the main determining factor in the degree of pest control is efficiency of spray application. There are now a large number of highly effective sprays available, but often it is the varying degrees of thoroughness with which they are applied that gives rise to conflicting opinions as to their efficiency. Any method, therefore, whereby the exact distribution of a spray on a plant can be determined, is of great value.

At the National Institute of Agricultural Engineering, R. B. Sharp* has been working on the use of fluorescent tracers. He developed the use of a fluorescent material in suspension, also the use of a water-soluble fluorescent dye in conjunction with a cellulose ether compound. Working independently, the present writer arrived at similar methods and has taken the work on to further stages of development, details of which have now been published.† A brief account here of the scope and use of fluorescent tracers in sprays and dusts may prove of interest to District Officers and other workers.

Fluorescent materials have the power to absorb ultra-violet light and re-emit it as light of a greater wavelength, which is then visible to the human eye and which can be photographed. Since the plant material on which the spray is deposited is usually non-fluorescent, or not strongly so, the deposit is very clearly seen. Where plant material is found to fluoresce, which may be in various colours, it is then a simple matter to choose a tracer for the spray which fluoresces in a different colour and so obtain the necessary contrast for viewing.

Methods of Application

Tracers may be used to simulate a spray or dust, or they may be mixed with an insecticidal or fungicidal spray, either as a suspension or as a water-soluble fluorescent dye with an adsorbent material in suspension or in solution. In particular, the writer has developed the use of oil-soluble fluorescent dyes which can be dissolved in the solvents used for many insecticides; where these insecticides are in a crystalline form, the dyes have the property of becoming adsorbed on the surface of the crystals when deposited and so pinpoint the actual insecticide deposit on the plant. The use of such dyes with DDT and endrin

*The Detection of Spray Deposits using Fluorescent Tracers. Tech. Memo. No. 119, *Nat. Inst. Agr. Eng.*, Silsoe, Beds.

†Fluorescent Tracer Techniques for the Study of Spray and Dust Deposits. *J. Agric. Eng. Res.*, 1959, **4**, No. 2, 110–25.

sprays are examples, and it is then possible to see on the plant, under a microscope, the needle-shaped crystals of DDT and the rhombic plates of endrin. (See Plate III (top)) Leaves are examined and photographed against a background of paper dyed with a fluorescent dye, so that the shape of the leaf is clearly defined.

Fluorescent solids are available in a variety of colours and some of the best are fluorescent pigments used in the printing trade. They are in a very fine state of division, remain a long time in suspension and fluoresce strongly. As little as 4 oz will "trace up" 100 gal of wash quite strongly. There are also luminescent powders, which differ from fluorescent powders by continuing to emit visible light for some time after activation by ultra-violet light. These have been found to be of particular value when investigating the mixing of insecticidal dusts with soils. All these powders may be mixed with insecticide dusts.

Water-soluble fluorescent dyes are also available in a variety of colours and small concentrations of these are dissolved in the diluted spray. An addition can then be made of an adsorbent solid, such as starch grains in suspension, and the starch then takes up the dye and fluoresces strongly. Alternatively, polyvinyl alcohol may be incorporated so as to give a dilute solution in the mixed spray. The spray, on drying, deposits a thin film of the polyvinyl alcohol containing the dye and this gives a very accurate picture of the spray distribution. (See Plate II.) Either of these methods may be used in connection with sprays which are solutions, such as lime sulphur, nicotine washes and similar materials.

Oil-soluble fluorescent dyes are soluble in a considerable variety of organic liquids, and small quantities of a dye of the desired colour are readily dissolved in a concentrate spray such as DDT, where it is in miscible form. When the concentrate is mixed with water and emulsification takes place, each droplet of the emulsion fluoresces under ultra-violet light. Under the microscope it is easy to observe the movement and gradual drying up and coalescing of the droplets, and the final deposition of the insecticide in crystalline form. (See Plate III (bottom)) By so doing it has been observed that there is always a strong concentration of the insecticide around the periphery of each dried-up droplet or area of spray deposit. These oil-soluble dyes may also be incorporated into emulsions of what are known as the "mayonnaise" type, by adding the requisite amount of dye to the concentrated emulsion and shaking it up well; the dye, being insoluble in water, soon finds its way to the solvent droplets and readily goes into solution. A range of dyes, of various colours, have been tested, and it has been found that their light fastness varies considerably; some are fugitive after a few hours, but others persist well for several weeks.

Despite the fact that some of them are rather expensive, the cost of fluorescent tracers in practice is small because only very small concentrations are required. For example, a pint of DDT miscible concentrate

spray may be "traced up" for less than 6*d*. These dyes may also be used in aerosol sprays applied by compressors of the "paint-spray" type and a technique has also been devised for tracing deposits from smoke generators.

Equipment Required for Examination and Photography

A mercury discharge lamp for the production of ultra-violet light is necessary for the examination of the finer deposits, such as DDT sprays, where the oil-soluble tracers are used. The bulb of these lamps is made of Wood's glass, which intercepts those rays harmful to the human eye and they are therefore very safe to use. The cost is about £8. For the simpler suspension tracers and water-soluble dyes with adsorbents it is sufficient to use a 150-200-watt ordinary electric bulb housed in a suitable box, with a front of Wood's glass. The examinations must be made in a dark or very dimly-lit room. A large box, with a black curtain over the front, to contain the lamp may be used satisfactorily.

Since the tracer techniques are simple and not costly, apart from the expenditure on an ultra-violet lamp, the larger growers and farmers might usefully set themselves up with the essential equipment and with a little assistance could carry out tests themselves, obtaining regular checks on the efficiency of their spraying.

When photographing deposits on plant material it is essential to use a deep yellow filter to cut off access of ultra-violet light to the plate or film, allowing only the fluorescent light to enter the camera. Fast panchromatic films and plates are used, and exposures for subject up to natural size or a little larger are usually around 30 seconds. Further magnification needs longer exposures of up to 1-1½ minutes.

A Valuable Advisory Tool

There is a very considerable field for the use of fluorescent tracers in sprays and dusts and in the study of methods for their application, and the technique has shown itself to be a valuable advisory tool. It has been possible to demonstrate to growers both the degree of efficiency of their spray applications and the merits or deficiencies of the machines used. It has also proved valuable in showing the run-off of sprays, which is such a common feature of high-volume, high-pressure spraying and has enabled growers to compare the type of cover obtained by the use of concentrate and low-volume machines, at the same time making them realize that the rather extravagant claims made for some types of machine are not always justified. The use of tracers has shown how such machines may be used in order to obtain satisfactory results. The effects of varying pressures, nozzle sizes and pressures can all clearly be demonstrated, together with the addition of wetters of various types and concentrations. Finally, knowledge of the exact

cover obtained by a spraying operation is clearly of great value when sprays are being tested against a pest or disease.

Other Uses for Tracers

Besides insecticides and fungicides in liquid or dust form, there is an obvious field in the application of weed-killers, which still remains to be explored by those interested in such materials. The problem of spray drift, which is of great importance, also lends itself to investigation on these lines.

Another aspect of spraying, which is now of great importance, is the question of the hazards attendant on spraying from the variety of highly poisonous sprays now in use. For instance, if such sprays were "traced up" the operators could be inspected quite quickly at the end of a period of spraying and be checked for skin and clothing contaminations. In the writer's opinion, the educative value of this would probably be high and lead to much greater care by workers.

Tracers have been used to study the efficiency of various cultivation methods for the incorporation of insecticide dusts in soils and also in the application of liquid insecticides, and the results have shown that the methods commonly used need to be improved considerably. Another application for the tracers would seem to be the study of the persistence of insecticides, but so far this problem has not been solved. Much depends on the relative persistence of the insecticide and of the tracer employed, the extent to which the insecticide may be absorbed by the plant, and many other factors. The method does, however, give some good indications as to the extent to which rain washes off spray deposits and has frequently demonstrated the much greater persistence of deposits on the under-surfaces of leaves compared with the upper surfaces. Work is also being carried out at Long Ashton Research Station where the matter of insecticide persistence is of special interest. The writer is in touch with workers there and the possible value of fluorescent tracers is under review, whilst analytical work is in progress.

CORRECTION

N.A.A.S. QUARTERLY REVIEW NO. 43

CEREAL VIRUS DISEASES IN BRITAIN

PLATES I-III These photographs should have been attributed to Mr. Frank Cowland.

PLATE III The left-hand photograph and the extreme right-hand one should be transposed.

Waste and By-product Limes

G. L. GRAY

Agricultural Lime Department, Ministry of Agriculture, Fisheries and Food

THE CONTRIBUTION towards farmers' liming costs under the Agricultural Lime Scheme has boosted the annual uptake of liming materials over the last twenty years from about 400,000 tons in 1937 to the present figures of 6-7 million tons.

During the same period the pattern of lime supplies has altered. Before 1937 the main forms of lime used for agricultural purposes were burnt lime and its derivatives, also lump chalk, ground limestone and ground chalk. During the war period, and particularly around 1942, the production capacity of the agricultural lime industry was insufficient to meet farmers' demands, mainly because of limitations of manpower and equipment. Consequently, other sources of readily available liming materials were sought. Suitable industrial by-product limes were discovered and exploited, and these continue to make a notable contribution to the range of farmers' lime supplies. The discovery of suitable types of by-product lime forms part of the functions of the Agricultural Lime Department's technical staff who are responsible not only for locating and testing the value of the available materials, but also for ensuring that they are maintained to agreed standards of quality.

The production of waste limes from all sources can be readily expanded during a period of peak demand. Thus, to a large extent, these forms of lime act as a buffer between demand and supply of the more conventional types of liming materials. During a bad liming season these industrial by-products may be only five per cent of the total national uptake, but in a good season they may consist of up to twenty per cent of total supplies.

"Waste" limes, which in fact are by-product limes from chemical processes, can be considered in two broad categories:

1. Non-recurring waste limes;
2. Recurring waste limes.

The non-recurring waste limes are by-products of chemical plants no longer in operation, and are found mainly in the Midlands and north-west. Most of them, so far as can be established, are derived from the Leblanc black ash alkali workings, of which those in the Widnes-St. Helens area are typical.

Exploitation of Non-recurring Waste Limes

In the Leblanc process common salt was treated with sulphuric acid to form sodium sulphate (with the formation of hydrochloric acid as a by-product). The sodium sulphate was mixed with powdered limestone and small coal and heated to form black ash, which gave rise to calcium

sulphide plus sodium carbonate. The sodium carbonate was extracted and the residue of insoluble impurities was known as alkali waste. The alkali waste contained valuable sulphur which was recovered by the Chance-Claus method, leaving a waste slurry of calcium carbonate. This slurry was run off into preformed lagoons where the lime settled to the bottom and the liquid was drained off. The lagoons, some of them up to five acres in area, were surrounded by walls of up to 20 ft high built of clinker and ashes, and the inflow pipes were supported by cement pillars. Some of the lagoons were grassed over afterwards and became local sports and football grounds.

When the time comes to exploit these deposits, it is necessary to air-dry the lime to make it sufficiently friable to spread evenly with mechanical distributors. Drainage trenches are made throughout the lagoons and the lime is excavated and built into "rucks" which are turned from time to time to assist drying. The final product has a liming value of about 35 per cent neutralizing value. Because of impurities these waste limes are variable in colour. White, green, yellow and black types are not uncommon, but colour gives little, if any, indication of their value as suitable agricultural liming materials. Other factors, such as possible contamination by toxic matter are much more important. Indeed, the contaminant may not necessarily be poisonous, in the usual sense. For example, a waste lime, similar in appearance to the white forms which farmers like, was recently rejected at an alkali works, because its high gypsum content rendered it unsuitable as an agricultural lime.

Whilst there are still quite large quantities of lime in some of these old lagoons, it may soon no longer be economic to exploit them because of the high moisture content, and the difficulty of selecting good lime from that mixed with various types of rubbish. Consequently, we may have to look to the recurring wastes or to the more traditional forms of lime to replace them.

Recurring By-products

Recurring waste limes are found in many parts of the country and arise in such industries as sugar purification, paper-making and water-softening. By far the most important from the tonnage point of view is the waste lime arising from synthetic nitrogen plants which use gypsum in their process.

Billingham and Prudhoe are the two centres of production of this kind of lime, both factories being owned and operated by the same company. From the point of view of agricultural lime, the latter centre is perhaps the more important, since production of calcium carbonate is about 1,000 tons daily. The lime can be transported direct from the works to the farm by rail or road, or from a vast storage heap which at present contains over 1 million tons.

The interaction of ammonium carbonate and gypsum gives rise to ammonium sulphate and calcium carbonate. The ammonium sulphate

is separated off and the residual calcium carbonate, containing about 2.0 per cent ammonium sulphate, is in a friable condition ideally suited for spreading on the land. Although this by-product chalk usually retains its spreading characteristics in the heap, in some parts and under certain conditions, a different crystal structure forms and sets into hard solid lumps. Before this lumpy product can be sold and used as a liming material it is necessary to crush the lumps to a fine powder.

Generally, the product from these works is similar in liming value to the products of the non-recurring sources, but because of its more recent and controlled origin it is always free from toxic materials.

SUGAR BEET WASTE LIME

Lime is used in the purification of beet sugar and a by-product slurry of calcium carbonate is run off into lagoons. The solids settle to the bottom and when the lagoons are drained and dry out, the lime is excavated and, if necessary, air-dried. It is then in a suitable condition to apply to the land.

The factories must take care to ensure that the lime slurry is not contaminated by soil washings, and from time to time the lime itself has to be examined to ensure that it is free from eelworm cysts.

Most of the sugar beet slurries contain small amounts of nitrogen and phosphates, mainly organic, derived from the tissues of the beet. If the rate of spread is high, the amounts of these fertilizer elements may be sufficient to affect fertilizer recommendations.

PAPER-WORKS LIME

Lime is probably the cheapest alkali in the whole range of the chemical industry. In paper-making it is used to neutralize acids, and a slurry of calcium carbonate similar to that found at sugar factories is produced. It is prepared in much the same way for application to the land, but before it is used a check should be made to see that the lime is free from sulphite toxicity.

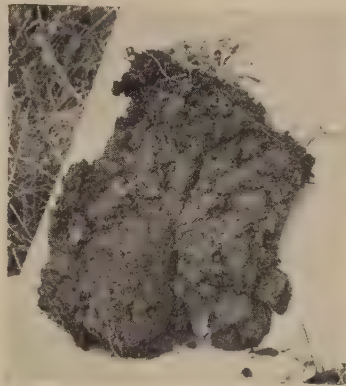
WATER-SOFTENING WASTE LIME

In most chalk areas and in many limestone districts the water is hard. However, some types of hard water can be softened by treatments which result in the formation of calcium carbonate. The lime slurry is run off into lagoons and after drying out it is excavated, air-dried and processed into a friable, spreadable lime supply similar to other wastes already described.

TANNERY WASTE LIME

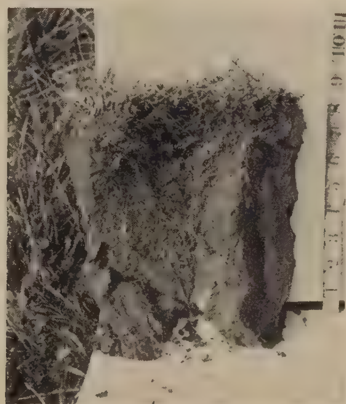
When preparing leather from green hides, the hides are steeped in a solution of calcium hydroxide. After some days this steeping results in the removal of hair, and most of the adhering fat tissue. The resultant by-product lime is a variable mixture of lime, hair and organic matter which is difficult to make into a form suitable for even spreading. However, it can often serve a useful agricultural purpose. At some tanneries the by-product lime may be contaminated with sulphite and therefore

SOME OBSERVATIONS ON SOIL DEVELOPMENT ON RESTORED OPENCAST COAL SITES (See pp. 147-53)



Left: Milkhope "hayed" profile, showing fissures and developing crumb structure.

Right: Milkhope "grazed" profile—compact with a prismatic structure, and less fissured.



Left: Cole Pike "hayed" profile illustrating excellent fissuring and good structure. A strong clover root is running across the profile.

Right: Cole Pike "grazed" profile, showing general compaction, prismatic structure and surface rooting. The soil is poorly fissured and root penetration restricted to the structure faces.

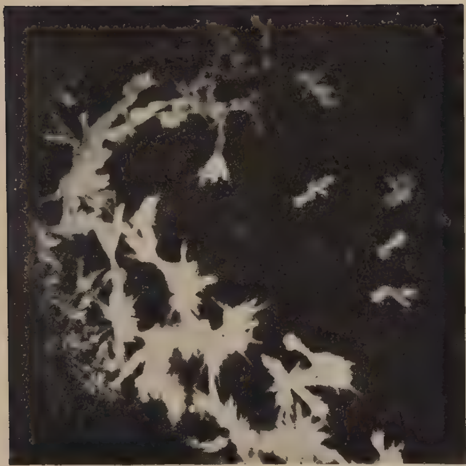
PLATE I

FLUORESCENT TRACERS IN INSECTICIDE SPRAYS AND DUSTS

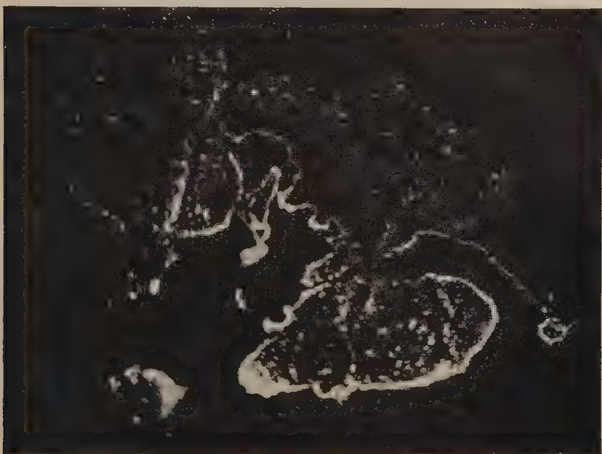
(See pp. 154-7)

When photographed under ultra-violet light, the spray deposit can be seen clearly on a strawberry leaf that has been sprayed with an insecticide "traced up" by the addition of a water-soluble fluorescent dye and starch grains in suspension. No spray deposit was visible on a "daylight" photograph.

PLATE II



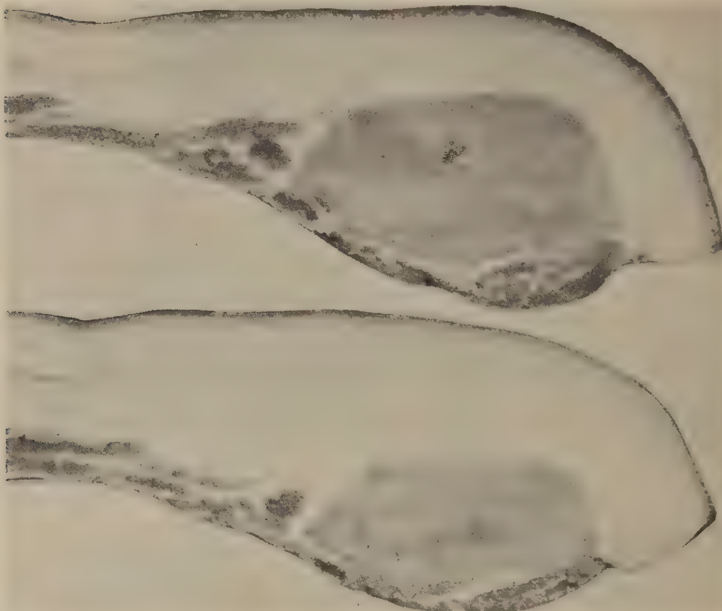
A DDT spray deposit on glass which gives excellent condition for good DDT crystal formation. The spray has been "traced up" with an oil-soluble fluorescent dye which has adsorbed on the surface of the crystals, so that they now fluoresce and show clearly in the ultra-violet light under which they have been photographed (× approx. 20)



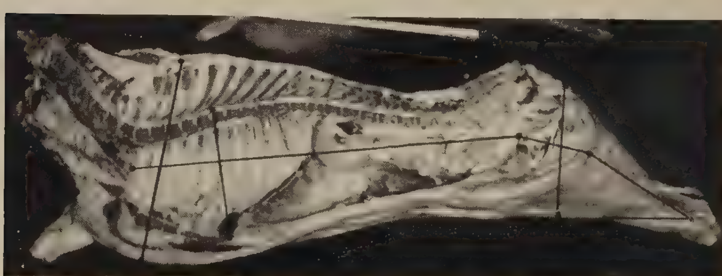
A DDT spray "traced up" with an oil-soluble fluorescent dye, as in the photograph above, but sprayed on to a leaf and then photographed by ultra-violet light. Note that there is a strong concentration of the DDT deposit around the edges of the sprayed areas. (× approx. 9)

PLATE III

RECENT DEVELOPMENTS IN THE ASSESSMENT OF CARCASS QUALITY (See pp. 172-6)



Rashers from two bacon sides with approximately the same backfat grading measurements showing: *Top:* an even fat cover over the "eye" muscle; *Bottom:* excessive fat at the corner of the "eye" muscle nearest to the streak.



A typical series of measurements for beef carcasses.

PLATE IV

it is necessary to establish whether tannery waste lime is free from toxic matter.

TAR DISTILLERY WASTE LIME

Arising from the purification of tar, some distillation plants produce limited amounts of waste lime. The product is usually very impure and may contain a significant amount of phenol. Such limes are unpopular because the impurities can cause severe scorching of grass; they must therefore be used with the greatest caution.

ACETYLENE WASTE LIME

The by-product from the manufacture of acetylene from calcium carbide is a moist colloidal hydrate of lime. At newer works a dry hydrate is produced, but it is rarely sufficiently pure to be attractive in the industrial market.

The wet hydrate is difficult to handle and, when fresh, contains gas residues which may be toxic. In the old days when acetylene waste was often available from small local gas works, it was frequently used in market gardens. It was dumped in small heaps and exposed to the weather for about six months before being added to the land. This kind of waste lime is now largely of academic interest as it is rarely if ever used in normal practice.

RECOVERED LIMES

At every burnt lime works there are waste heaps of partially-burned stone and kiln rejects. From time to time, especially when supplies of burnt lime are scarce, efforts are made to recover lime from these waste heaps. The material in the dumps, if sufficiently dry, is excavated and screened. The unburned stone cores are rejected, and the material which passes the screen consists mainly of calcium carbonate, reverted hydrate, and sometimes a little free burnt lime. Screening produces a material suitable for mechanical spreading, and when such products are available they are useful replacements for freshly burnt limes but have only slightly more than half their liming value.

LIMESTONE DUST

In the production of graded limestone for ballast, concrete work, road stone, chemical processes, etc., there arises a coarsely-graded dust known as crusher dust or limestone dust, varying in composition from very fine particles, to those about $\frac{1}{4}$ in. in diameter. Formerly such dusts were available, as produced, for liming rough grazings and grass fields, particularly in the wetter and hillier areas. More recently producers have processed these dusts by further screening and thus produced a more attractive product. These screened dusts are now usually guaranteed to meet a grading specification of "All through $\frac{1}{8}$ in., 30 per cent through the 100 mesh". (The 100 mesh is the British standard test sieve having 10,000 holes to the sq. in.). These dusts can be regarded as slow-acting ground limestones. Experiments have shown that they are suitable for

use in the wetter areas. Economically, their value depends largely on delivered costs, and within short distances of the production points they compare favourably in cost with alternative lime materials.

WHITING WASTE

At a few centres in the chalk belt where whiting is manufactured, the over-sized particles are offered for agricultural use under the general term "whiting waste". These products are coarsely-ground chalks and, as such, are well suited for use on the land. They are not usually so dry as a true ground chalk but when sold are in a condition fit for spreading.

HYDRATOR TAILINGS

Hydrated lime is produced both from limestone and from chalk and is available at many centres throughout the country. The demands for hydrate from industrial users are met by the purest product obtainable. A significant quantity of reject material is available to agriculture. Products known as hydrate tailings or rejects consist of particles of unburnt stone, burnt lime and hydrate, the impurities of the original stone and the ash residues of the fuel used to burn the lime.

In practice, these rejects have a liming value of about two-thirds that of a good burnt lime and are thus slightly better than ground carbonates. Some farmers take the view that the quicker action of the burnt lime and hydrate fractions in products of this kind is a distinct advantage, whereas the long-term action of the carbonate fraction is useful for the following crop.

An Assessment

The price to merchants of these waste limes generally ranges from about 2*s*. to 10*s*. per ton ex works, depending on the cost of preparation for agricultural use. At these price levels they compare favourably with ground limestone and burnt lime, and farmers who live close to a source of production of waste lime would be well advised to consider using such materials rather than pay higher costs for alternative forms of lime. These waste and by-product limes contribute significantly to the national tonnage, and there are many farmers who use them constantly. Their exploitation has contributed in no small part to the agricultural lime-spreading industry, but because of their origin, it is essential that they be kept under constant supervision, with frequent checks as to quality, and, in certain cases, as to toxic content.

There is a wide variety of liming materials suitable for agricultural use in this general category of by-product limes. They should not be overlooked or rejected for reasons only of name, low cost or colour. In many districts within reasonable distances of the production centres they are by far the cheapest forms of lime available to farmers. Because of the impurities or high moisture content heavier dressings may be required; thus it is only by careful selection and weighing up all the costs that their proper worth can be determined.

Leys and Soil Fertility

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SYSTEMS of husbandry in which arable crops alternate with leys are generally considered to be of great benefit to the production of the arable crops in the rotation. The precise methods by which leys influence soil "fertility" and the information on whether different types of ley, or management of those leys, have important effects on the yields of subsequent crops, can only be ascertained as the result of detailed long-term experiments. The results of some experiments of this type have recently been published, and there is general agreement in these papers that both the type and management of the ley can influence the yield of the following arable crops.

Age of Ley

The superiority of the three-year ley when compared with a one-year ley, in terms of increased arable crop yields, has been effectively demonstrated by Mann and Boyd [1]. The experiment which they describe has been in progress since 1937, and is situated on a sandy-loam soil passing at from 1-2 ft into a yellow loamy sand derived from the lower Greensand. The first test crop grown after ploughing up the leys was potatoes and the yields after a three-year ley, a one-year ley, and a rotation with no ley at all, were 13.1, 11.6, and 10.6 tons of potatoes respectively. Similarly, on soils consisting of chalk-with-flints at the Grassland Research Institute [2], better yields of wheat have been obtained after three-year leys than after one-year leys. The increase in the yield of wheat varied from 4-15 cwt grain/acre, depending upon the management imposed on the three-year ley.

Whilst alternate husbandry can increase crop yields, the individual factors involved are many and, because of complicated interactions, have not yet been clearly defined. Some of the more important changes resulting from a period under grass are the increase in soil organic material, improvements in soil structure and a reduction in the amount of pests and diseases of arable crops. Both Low [3] and Clement and Williams [4] have shown that the stability of soil, as measured by water-stable aggregation, increases the longer the land has been down to grass. However, it is fairly clear from both these papers that the distinct increases in water-stable aggregation brought about by three-or four-year leys sown on arable land are relatively small in relation to conditions under old permanent grassland. Low concluded that, except for very sandy soils, many years under grass are required to restore arable soils to the structural condition found under old grassland. With clay loams this period is likely to be greater than 50 years, whilst on sandy loams, with free drainage, it may be completed in 5-10 years.

Sward Composition

There is evidence that the botanical composition of leys may have a profound effect on the subsequent yields of arable crops and in particular, the proportion of legume in a sward is most important. Thus, the relative wheat yields after a clover-dominant sward, balanced clover-grass sward and all-grass sward, were 36, 33 and 28 cwt/acre [5]. In addition Aldrich *et al.* [6] have shown that the strain of clover may be important in determining the yields of subsequent crops. Potatoes were grown after ploughing a grazing trial which had compared four strains of white clover. Kent clover was the most persistent, produced the greatest liveweight gain per acre, and gave the highest yield of potatoes. The Dutch White clover, which had been the poorest in the grassland trial, gave the lowest yield of potatoes. Clement and Williams [4] have shown that there are differences in the build-up of water-stable aggregates under swards composed of different species. An interesting point is that in eight different experiments, ryegrass-white clover swards tended to have a greater effect on water-stable aggregation than cocksfoot-white clover. In addition, the build-up of root material was also greater under ryegrass than under cocksfoot.

Despite the apparently better soil conditions which resulted from the ryegrass-white clover ley, the yields of wheat tended to be lower than after cocksfoot-white clover [2]. A contributory factor to these apparently contradictory results may have been the different degrees of stem-boring larvae infestation which followed ryegrass and cocksfoot. The attack of these pests on wheat was much greater following ryegrass than after cocksfoot. Another experiment in this series confirmed this point and showed that severe infestations followed the ploughing of swards dominated by perennial ryegrass, *Agrostis tenuis*, red fescue, smooth-stalked meadow grass or rough-stalked meadow grass, while moderate or light attacks followed swards mainly composed of cocksfoot, Yorkshire fog, timothy, meadow fescue or tall fescue. In these experiments the yield of wheat was severely affected by stem-boring larvae when infestations were heavy. It appears from these results that it is unwise to think that the fertility build-up under grass swards may be expressed simply in terms of either organic matter or soil structure. Other factors such as the carry-over of pests and diseases may be of over-riding importance in certain years or rotations.

Fertilizer Management

Experiments at the Grassland Research Institute [2] have shown that the level of nitrogenous fertilizer application to leys may have an important influence on the following crop, but the effect may vary depending upon the method of utilizing the ley. Thus, where leys were grazed throughout their life, increasing the application of "Nitro-Chalk" to 16 cwt/acre/annum to the grass sward resulted in increased yields of the

following cereal crop. On the other hand, where the grass was cut and removed, increasing the application of nitrogen to the sward tended to lower the yield of the subsequent wheat crop. Kale followed the wheat, with a similar pattern in yield. These results were obtained in the presence of liberal dressings of phosphate and potash. Wheeler [7] also found that, provided all the animal excreta were returned, the higher the level of nitrogenous application to a grazed ley, the greater the yields of the following arable crop (either wheat or kale). In contrast, where no animal excreta were returned, the arable yields tended to decline as more nitrogen was applied to the ley.

An interesting result has been obtained at Wye where potatoes were grown after a clover strain trial (Aldrich *et al.* [6]). Different levels of nitrogen, phosphate and potash were applied to the potatoes. The application of nitrogen caused a significant reduction in potato yield, this reduction being more marked after the more persistent and higher-yielding clovers. The highest yields of potatoes were, in fact, obtained on the plots which received no nitrogen and which followed the clovers which had produced the most herbage yield. This reduction in potato yield as a result of applying additional nitrogen was thought to be partly due to the high soil fertility conditions of these experiments—probably due to the past history of the field rather than to the direct effect of the leys.

Sward Management

Leys which are grazed have been shown to have a better effect on subsequent crop production than leys which are continually cut for conservation even when liberal dressings of nitrogen, phosphate and potash are applied to the swards [2]. Seed crops, particularly if grown in wide rows, also appear to result in lower cereal yields than grazed swards [5]. With cocksfoot grown for seed production in rows 2 ft apart, the crumb stability of the soil is low, particularly between the rows. Wheeler [7] has studied the effect on subsequent yields of wheat and kale of animal returns of dung and urine during the grazing of leys. Yields were greatest where both dung and urine were returned and lowest when these were withheld. The application of urine alone was relatively ineffective except in combination with nitrogen.

Two articles—Williams *et al.* [8] and Hanley *et al.* [9]—have reported the effect of the final management of leys immediately before ploughing on the yields of the following crop. Williams, *et al.* [8] carried out experiments on three-to-four-year-old leys, and found that the final treatment during the month preceding ploughing had very little effect on subsequent crop production. It was concluded that as far as medium duration leys were concerned, neither the quantity of herbage ploughed in nor the presence of recently deposited animal excreta, in amount equivalent to that produced at a single grazing, affected critically the yield of the following cereal crop. Differences in the yield of wheat crops

following leys managed in various ways are likely therefore to be the result of cumulative effects and are not due to variations in the amount and quality of ley residues which arise a short time before ploughing. Whether the last growth of herbage is ploughed in, grazed off, or cut and removed, does not appear to influence the yield of the subsequent cereal crop. Similar results to these were obtained by Hanley *et al.* [9] who carried out their experiments on a one-year ley.

Clement and Williams [4] showed that the major effect of a three- or four-year ley on soil structure is confined primarily to the top inch of the soil profile. Under a three-year-old ryegrass-white clover ley, the percentage of water-stable aggregates larger than 0.5 mm in the surface 2 cm of soil was three times greater than in the 2-4 cm horizon. The authors point out that ploughing a ley will bury the well-aggregated and stabilized topsoil, and bring to the surface material little affected, in terms of water-stable aggregation, by the preceding grassland. When the ploughed layer is mixed by subsequent cultivations, the water-stable aggregation of the surface soil will depend upon the depth of ploughing in relation to the profile characteristics and magnitude of the increase in water-stable aggregation affected by the ley. It may be, therefore, that the traditional method of ploughing does not give the most efficient utilization of the beneficial effects of leys by the subsequent arable crops.

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The Bacteriology of Silage

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THIS REVIEW will attempt to survey some of the general principles which have been found to apply to silage fermentation. Of necessity, many aspects of ensilage practice and plant chemistry, which are inextricably linked with the subject, must be omitted. The literature cited is very obviously a short selection, but much of it provides many additional references to pertinent work. The books of Watson [45] and Barnett [3] and a bulletin of the Commonwealth Bureau of Pastures and Field Crops [8] are the chief sources of literature on silage fermentation and related subjects.

Bacteria of Fresh Herbage

Acids which aid in preserving the herbage are provided by the action of bacteria on the plant sugars; consequently the bacteria on the plant material assume importance. The presence of populations of bacteria on the aerial parts of plants has long been recognized [6 and 11]. The majority of the epiphytic bacteria are strict aerobes which can form little acid from sugars [11, 9, 23 and 14]. Gram-negative facultative anaerobes are much less numerous than the strict aerobes [2, 23 and 14]. *Bacterium herbicola* appears to occur regularly [e.g., 11 and 25] and many investigators have made estimates of coliform organisms [20, 17, 18 and 2]. Most coliform types remain undetected in media incubated at 37°C [1 and 43]. *Escherichia* is less frequently encountered than *Klebsiella* [19, 43 and 13]. Neither *Bacillus* nor *Clostridium* have been found to occur numerously on fresh plant material [39, 34, 30 and 26]. *Streptococcus*, *Leuconostoc* and *Pediococcus* appear to be relatively scarce [35, 31 and 14]. Much variation has been reported in the rate of occurrence of *Lactobacillus* and of organisms which were presumed to be lactobacilli because of their ability to grow on selective media [40, 21, 20, 18, 22, 2, 41, 23, 26 and 14]. Several of the reports show that this group of bacteria, which is believed to have a special importance in the acidification of silage, may be very sparsely distributed on growing crops. Some of the higher counts which have been reported were possibly not obtained from fresh herbage; bacterial multiplication may occur during the wilting and harvesting of a crop [23].

Early Multiplication Phase

Where silage has been examined at appropriate times, a regular sequence of events has been demonstrated. Fresh herbage quickly consumes the entrapped oxygen if air is excluded [29]. The aerobic bacteria of the herbage then die rapidly [24 and 14]. Organisms capable of anaerobic

growth (species of *Streptococcus*, *Leuconostoc*, *Pediococcus*, *Lactobacillus*, *Clostridium* and *Bacillus*, *Bacterium herbicola* and the coliform group) proceed to multiply if any are present. The period of multiplication lasts for only a few days in the range 22°-40°C (72°-104°F), and it is followed by a phase of decreasing viable count. The rate of growth and the final density of the bacterial population vary with the herbage and the temperature [14].

Rapid multiplication to a high peak count followed by a steep decrease in viable bacteria has been regarded as distinguishing a good fermentation from a bad one [31]. Evidence has been obtained that the several groups of typical silage bacteria do not differ much in rate of growth or in the time at which their multiplication starts or finishes, provided the temperature is suitable for the organism [14]. The replacement of Gram-negative rods by cocci, and finally the dominance of lactobacilli has often been demonstrated by non-quantitative methods. This sequence appears to be attributable to powers of survival and not to overgrowth, at least during the early period. Since the multiplication phase is commonly completed before much acid has accumulated, the bacterial growth appears to be limited largely by nutritional factors. This receives support from the finding that lactic acid bacteria do not become dominant if other organisms multiply much more extensively [39]. Furthermore, a noteworthy growth of bacteria has been shown [28, 9 and 30] to occur in silage acidified by mineral acids (the AIV process) to pH values less than 4. Acids commonly continue to accumulate in silage after the lactic acid bacteria have reached the phase of decreasing viable count [12 and 29]. This cannot be attributed to the continuing multiplication of one group, such as the lactobacilli [14]. It seems necessary to assume that during the first weeks acids are formed by bacteria which have ceased to grow or have lost their viability.

Later Stages

Little coherent information is available on the bacteriological changes during the period in which silage is stored. Most of the records do not distinguish growth from survival, and many are complicated by variation among the samples taken from a large silo. Where silage has not been stabilized by acid or other factors, a renewed bacterial growth is to be expected when further nutrilites are liberated from the plant tissues and autolysing bacteria. A secondary growth of pedicocci has been demonstrated [24], and much evidence on the time of appearance of fermentation products shows indirectly that clostridia may develop after weeks or months.

The fermentation of lactate with the production of butyric acid by clostridia has been shown to be the most important feature of deterioration [4 and 5]. It may be noted, however, that a reversal of pH has been found in silage in which no butyric acid could be demonstrated [15], and also in silage in which neither clostridia nor butyric acid were

detected [33]. The survival of bacteria in ageing silage has been found [20, 36 and 5] to be extremely variable. In stored silage of both good and bad quality, lactobacilli or the combined groups of lactic acid bacteria have been reported to be the dominant organisms in some specimens and totally absent from others. In the present state of knowledge, a bacteriological analysis of aged silage can yield little indication of the earlier events or of the quality of the product.

Properties of the Herbage

The concentrations of soluble carbohydrates and other constituents of the herbage may have a dominating influence on the bacteria, but this subject cannot be adequately discussed here. Juice exuded from the plant tissues is believed to be the medium in which bacteria multiply [31]. The advantages of an early and rapid production of lactic acid can be obtained by mechanical treatments which liberate juice [16]. Addition of water can have a similar effect [15], but in practice this procedure has serious drawbacks. The greater the water content, the more difficult it becomes to secure a rise of temperature and the more destructive are harmful changes during storage. The effects of an excess of water can become intense when drainage is impeded. It is noteworthy that AIV silage with a pH value less than 4 is spoiled if it is not drained [44].

The literature on the ensilage of wilted crops indicates that the drier the herbage the less will be the bacterial activity in the silage and, if oxygen can be excluded, the more certain will be the preservation. With increasing dry matter content the smaller becomes the role of fermentation acids as factors in the preservation. Clostridia appear to be relatively intolerant of dry conditions while certain lactic acid bacteria are resistant. Lactobacilli have been reported to be the dominant organisms at 70 per cent dry matter [42]; significant amounts of lactic acid have been found when the dry matter exceeded 50 per cent [10]. Dilution of juice, which would occur with ingress of rain water, selectively favours Gram-negative organisms [32] and promotes the production of acetic acid [5].

Temperature

In silage prepared at 40°C (140°F) and at 22°C (72°F) Gram-negative bacteria were found to be restrained at the higher temperature, *Clostridium* and *Bacillus* at the lower [14]. At 45°C (113°F) and upwards the development may be restricted to species of *Bacillus* [7]. The biochemical changes in a range of temperature from 37°C (99°F) downwards have been examined in recent work with nitrogen-rich crops [27 and 38]. Undesirable changes, more especially the formation of butyric acid and ammonia, were generally most active between 28°C (82°F) and 37°C (99°F). Some silage failed to preserve unless it was held below 20°C (68°F). These findings, which confirm others obtained previously,

suggest that benefits secured by raising the temperature in farm silage derive from non-bacterial changes in the plant material. Heating appears to overcome in some measure the disadvantages associated with a more than optimal content of water in the herbage.

Additions

It is impossible to review briefly the extensive literature on adding various materials to herbage with the object of improving the preservation of silage. Some general principles may however be mentioned.

Where additions are made by hand during the filling of a silo, stratification and the occurrence of untreated pockets are almost inevitable. The importance of mixing was first emphasized in relation to treatment with mineral acid [4]. Some adequate mechanical process is so far the only answer to the problem.

Where substances are applied in solution, the volume of water should be restricted to the necessary minimum, partly because water usually militates against preservation, and partly because it increases the loss of solids in the effluent. For these reasons, interest has been taken in applying undiluted molasses with pressure sprayers. Whey is often suggested as a source of sugar, yet consideration of its water: sugar ratio shows that it must be unsuitable unless it has been concentrated.

Uncooked starch grains resist the action of the amylases of green herbage and are apparently unavailable to the lactic acid bacteria of silage. Yet cereal meals have given some benefit, at any rate when added generously. This has been attributed partly to their small sugar content and partly to their capacity to absorb water. Mixtures of meal and malt have been found more beneficial [37].

Practical Considerations

A common observation is that well-preserved silage is made on one occasion but not on another by essentially the same method. This is perhaps not surprising in view of the complexity of the bacteriological and chemical changes in the material. The properties of the herbage can have a decisive effect. It is well established that a crop is in the least suitable condition for making silage when it contains little soluble carbohydrate but much water. This condition develops most acutely in wet, sunless, warm weather. The preservation of such herbage can be achieved if bacterial activity is reduced by wilting to a dry matter content of 30-35 per cent or by the addition of mineral acids or other bacteriostatic agents. Adding carbohydrates and promoting a rise in temperature are other measures which can alleviate an unfavourable condition of the herbage. Mechanical treatments which liberate juice, and so accelerate bacterial action, appear to be wholly beneficial. They cannot, however, ensure preservation if sugar is severely deficient. Free drainage and the exclusion of rain water promote stability in silage of

any type. All these considerations apply solely to preservation in the silage itself. They do not cover losses in the effluent, or those incurred during wilting, and they make no allowance for the costs of the methods.

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Recent Developments in Assessing Carcass Quality

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FOR MANY YEARS experiments with meat animals included very little in the way of data on the composition and quality of the carcasses produced, and records tended to be restricted to rate of growth, economy of food conversion and perhaps commercial grade. Recently there has been a growing realization of the inadequacy of this type of information, which has been strengthened by the need for methods of carcass evaluation in connection with schemes for progeny-testing boars and beef bulls. Experience with bacon carcass competitions over a number of years has shown that breeders are intensely interested in carcass quality provided it can be described in reasonably straightforward, unambiguous terms. This has been done in respect of the bacon pig by means of a scorecard (Table 1) in which the quality characteristics are itemized and marks awarded according to their relative importance.

Table 1

	Maximum Marks
MARKS FOR MEASUREMENTS:	
Length for weight	10
Thickness of shoulder backfat	10
Thickness of rump backfat	10
MARKS FOR INSPECTION:	
Size and shape of eye of lean	15
Proportion of fat on back rasher	10
Firmness and whiteness of fat	5
Streaks: thickness and proportion of lean to fat	10
Shoulder neatness	15
Gammon: shape and size	15
	100
PENALTY MARKS:	
Excessively soft fat	5
Bad flesh	5
Seedy cut	5
Excessively coarse rind	5
Lack of finish	5

The Educational Value of Carcass Competitions

When the carcasses have been judged, the marks awarded are placed on a card beside each exhibit so that the producer can see at a glance the particular features in which his exhibit has failed. It is generally recognized that in this way these carcass competitions have had great educational value and have done a great deal to facilitate the introduction of pig progeny-testing. Unfortunately a similar method has not yet been developed for judging beef carcasses, although the need is at least as great as it was for bacon, since most of our beef is produced as a by-product of the dairy industry, yet it has to compete with imported beef which is not only produced from beef-bred cattle, but is also specially selected in the country of origin.

Assessment of carcass quality can be considered under two broad headings:

1. Conformation and composition of the carcass.
2. Characteristics which affect the saleability of the meat but which are not necessarily related to carcass composition.

Under the latter heading may be included the colour and texture of muscle, the shape of the longissimus dorsi muscle in lamb chops, and the width and thickness of the streak in bacon sides. The straightforward method of determining carcass conformation and composition is by means of an appropriate dissection technique, but as such techniques tend to be both laborious and expensive, it is hardly surprising that a good deal of effort has been devoted to elaborating methods which avoid dissection. The value of these methods must, however, remain rather speculative in the absence of a solid basis of dissection data to which they can be related.

Broadly speaking there are two types of dissection techniques available: commercial dissection, or anatomical dissection. In commercial dissection the carcass is first of all jointed in a recognized commercial fashion and the individual joints are then separated into bone and fat and muscle. It has the advantages that it can be carried out fairly rapidly with the type of skilled labour normally available in meat packing plants and bacon factories, and the results can readily be interpreted in terms of commercial value. It has the disadvantage that methods may vary considerably from place to place and from time to time, so that the results may lack the absolute precision desirable in experimental work and, furthermore, provide no data on the growth and development of individual bones and muscles.

A more anatomical type of dissection, developed by Hammond and used extensively by the Cambridge school, involved the preliminary division of the carcass into anatomical regions and the subsequent dissection of each of these into its component tissues. However, this method involves the cutting of some very important muscles, for example, the longissimus dorsi was divided among the thorax, loin and pelvis, and in recent years strictly anatomical techniques in which

practically all the individual muscles of the carcass are dissected have been developed notably in New Zealand and in Sweden. A logical development of this type of work would appear to be the anatomical dissection of one side of a carcass combined with a commercial dissection of the other.

Attempts have been made to reduce the labour and cost of dissection by restricting the dissection to sample joints, for example, one or more rib joints in the case of beef. Rib joints can be removed from a beef forequarter without drastically depreciating the value of the side as a whole, and have therefore been preferred to the loin, which gives a better estimate of the composition of the carcass, but is unfortunately a very valuable joint and moreover, cannot be removed without cutting up the whole hindquarter.

Carcass Measurements

Even the limited dissection of sample joints may be too laborious for some purposes, particularly genetic experiments involving large numbers of animals. For such experiments carcass measurements have been used extensively to describe the carcass, although their value for determining carcass composition is rather doubtful. For example, in the bacon pig the thickness of backfat in the middle line of the carcass is normally closely related to the total fat in the carcass. However, the thickness of backfat in the middle line may often be quite small but the thickness at the corner of the "eye" muscle furthest from the mid line may be excessive (Plate IV (top)). This suggests that selection for thin backfat in the mid line may in some instances merely result in the redistribution of the same total amount of fat in the carcass.

A typical series of measurements for beef carcasses is shown in Plate IV (bottom), from which it will be seen that most measurements are made between well-defined skeletal landmarks; consequently, in so far as these measurements prove to be related to carcass composition, they are more likely to be related to the amount of bone than anything else. The precision and repeatability of carcass measurements has been studied in recent years. Precision is largely a function of the definition of the measuring landmarks, thus, in beef carcasses, length of body from the anterior edge of the symphysis pubis to the middle of the anterior edge of the first rib is a much more precise measurement than the maximum width of carcass where the position of the measurement must be judged by eye. The length measurement is also highly repeatable between different observers whereas two observers may measure the width measurement with equal precision yet record widely differing absolute values.

The backbone of the bacon pig is removed from the carcass and it has been shown that considerable variations in the length of the carcass can occur after slaughter. These changes are probably caused

mainly by post-mortem contraction and subsequent relaxation of the muscles of the abdomen, and emphasize the importance of taking measurements as soon as possible after slaughter. In the bacon pig it has also been shown that the diameters of the cross-section of the longissimus dorsi muscle can be markedly affected by the position of the side in the pickling tank and in the maturing stack, so that where these measurements are to be taken on bacon sides it is best for the position of the sides in the tank and stack to be the same.

Aids to Visual Judgment

Expert visual assessment still plays an important part in carcass assessment and is likely to continue to do so where large numbers of carcasses have to be assessed in a short time as in carcass competitions. Recently, the accuracy and repeatability of visual assessments have been studied using full-size photographs of the lean and fat in a surface exposed when the bacon side is cut across at the level of the last rib. It has been shown that an expert's judgment of a particular photograph was considerably affected by the average quality of the batch in which it occurred. In other words, the marks awarded to a particular exhibit in a carcass competition tend to be affected by the average quality of the other exhibits. Furthermore, although the repeatability and discrimination of the judgment of experts was much greater than that of comparative novices, the judgment of the latter approximated to that of the experts when they were provided with a set of standard photographs. These experiments suggest that visual judgment can be greatly improved by the use of photographic standards, and further work is continuing with other and more difficult features of the carcass such as shoulders and gammons.

Determining Carcass Composition in the Living Animal

During recent years, and particularly in the U.S.A., a good deal of attention has been paid to performance testing of boars and beef bulls. Performance testing measures the breeding value of a sire by his own rate of growth and economy of food conversion as opposed to progeny testing which measures these characteristics in his offspring. Performance testing has the advantage that the test is completed while the animal is still young, but it does not provide the information about carcass quality that is obtainable with progeny testing.

Consequently, efforts are being made to develop methods of determining carcass composition in the living animal. For example, backfat thickness has been measured in living pigs by means of mechanical and electrical probes and, more recently, by means of the reflection of an ultrasonic beam from the interface between the subcutaneous fat and the underlying muscle. The latter method is interesting because it should enable the backfat thickness to be mapped out without inconvenience to the pig. However, at the moment, both the probes

and ultrasonic apparatus will only measure thickness of backfat, whereas the real need is for a measure of development of muscle. The ultrasonic apparatus seems to offer the most promise in this direction, since theoretically it should be possible to reflect the beam not only from the fat-muscle interface but also from the lateral processes of the lumbar vertebrae which underlie the longissimus dorsi muscle and to obtain the thickness of the latter by difference.

Another method of determining the amount of muscle *in vivo* has also been investigated in the U.S.A. and depends on the estimation of urinary creatinine. Creatinine in urine is wholly endogenous in origin, that is to say it is derived from body muscle metabolism and is independent of the protein or non-protein nitrogenous constituents of food. The output is affected by muscular exercise but tends to be constant over periods of twenty-four hours, so that there is a direct relationship between the amount of urinary creatinine and the amount of muscle in the body. This method is still under investigation but it seems promising and it is probable that eventually a combination of various methods may give an accurate estimate of the amount of muscle in the body of the living animal.

Scientific Principles of Livestock Feeding: Part II*

(Continuing a summary of the papers presented at the Brighton Conference 11th to 13th November, 1958)

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Sheep

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MAINTENANCE REQUIREMENTS

Only a few experiments have been carried out to determine the *fasting, resting metabolism*. A fast of at least three days is necessary for ruminal fermentation to subside. In this state, ewes of breeds as different as the Merino and the Dorset Down gave results, measured as metabolizable energy, within the narrow limits of 66 to 69 kilocalories $\times$ $W^{0\cdot73}$/24h (where W is the live weight in kilogrammes).

*Part I was published in the *N.A.A.S. Quart. Rev.*, No. 43, 111-19.

This agreement was obtained with ewes of 16 months and upwards, and a similar result was obtained with Cheviot wethers of 15 months.

The *metabolizable energy* required to *maintain sheep in energy equilibrium*, i.e., the "maintenance requirement", was found to be $88 \times W^{0.73}$ kcal/day for Merino ewes and $100 \times W^{0.73}$ kcal for Cheviot wethers. To express these figures as starch equivalents it is necessary to make deductions from the gross energy of the food: 9 per cent is lost in methane and 6.5 per cent in the urine, leaving 84.5 per cent to be used for maintenance. The gross energy of starch is 4.2 kcal/g and 84.5 per cent of this is 3.55 kcal. If, therefore, the metabolizable energy in kcal is divided by 3.55, the grammes of S.E. for daily maintenance are obtained. Table 1 shows the results recalculated in terms of *lb S.E./week* to provide an easy comparison with the feeding standards given in the Ministry of Agriculture's Bulletin No. 48 "Rations for Livestock" (13th Edition).

Table 1
Maintenance Requirements of Sheep (lb S.E./week)

Weight of Sheep	Feeding standards in "*Rations for Livestock*"	Calculated from $88 \times W^{0.73}$kcal (Merino ewes)	Calculated from $100 \times W^{0.73}$kcal (Cheviot wethers)
lb			
60	6½	4.3	4.8
70	7	4.8	5.4
80	7¾	5.3	6.0
90	8½	5.7	6.5
100	9	6.2	7.0
110	9½	6.7	7.5
120	10	7.1	8.0
130	10½	7.5	8.5
140	11	7.9	9.0
150	11½	8.3	9.5
160	12	8.7	9.9

The values in the two right-hand columns of this table apply to caged sheep with exercise limited to standing up and lying down. Even so, the discrepancies between these values and those of "*Rations for Livestock*" are so large that they are more likely to arise from the mode of calculation than from the degree of exercise. It is likely that a sheep would have to walk 15 miles a day to require the maintenance recommended by "Rations for Livestock".

Phillipson considers that the explanation lies in the probable use of the fat-formation value of 1070 kcal/lb (2.36 kcal/g) in calculating the "Rations for Livestock" values. But at energy equilibrium (maintenance), starch must have a higher value for maintenance than for the less efficient process of fat formation. Had the factor 2.36 been used

in place of 3.55 when calculating the values for the Merinos, figures very close to those in "Rations for Livestock" would have been obtained. This strengthens the suspicion that the latter figures are too high in consequence of the use of the conversion ratio of starch to fat in bullocks.

This view is supported by experiments on Border Leicester × Cheviot ewes which showed maintenance requirements of 6.4 to 6.8 lb S.E./week for a 100-lb ewe, and by others on fattening sheep which showed a requirement between 6 and 7 lb S.E./week for a 100-lb animal. These results are in good agreement with the figures calculated by the factor 3.55 in Table 1, and the circumstantial evidence indicates a *prima facie* case for revision of the present standards.

FEEDING IN PREGNANCY

The foetus has attained only 5 per cent of its birth-weight by the 70th day of pregnancy and the uterine wall, cotyledons, etc, although much further developed, have not put much demand upon the ewe at this date. Hence feeding up to the 70th day need not much exceed maintenance requirements. Indeed, a large increase in weight in the early stages is to be avoided, particularly if a check in feeding occurs in the later stages. Underfeeding in the last two months can lead to pregnancy toxaemia, and supplements during the last 6 to 8 weeks (following restricted early feeding) give good results.

Increase of daily feed to a total of 2.65 lb gross digestible energy* in the form of sainfoin hay and concentrates in the last 6 weeks of pregnancy was found by Wallace to be satisfactory for Border Leicester × Cheviot ewes judging by the weights of the lambs and the weights of the ewes after lambing. In the earlier part of pregnancy only sainfoin hay equal to 2 lb G.D.E./day had been given and all ewes that received no concentrates during the 6 weeks before lambing lost weight. There was a relation between the plane of nutrition in the last month and the birthweights of twin lambs.

Work by Thomson and Thomson seemed to show that the production of twin lambs was more economical in energy than singles. This is shown by the data in Table 2. The G.D.E. is based on "Rations for Livestock", 1939, and is really metabolizable energy.

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*Phillipson recommends that "gross digestible energy" should be defined as "calorific value of feed minus calorific value of faeces". This differs from the form of G.D.E. used by Wallace which is that listed in the tables of former editions of "Rations for Livestock", e.g., the edition of 1939. This second form is merely another way of expressing metabolizable energy as it takes account of methane loss, fat impurities, and the urinary excretion of combustible compounds. Phillipson would prefer to have M.E. and the second form of G.D.E. both referred to as "available energy", with the qualifying adjective "measured" if it has been directly determined in a calorimeter or "calculated" if calculated from digestibility coefficients.

Table 2
Mean Values for Food Consumption, Ewe Weights and Lamb Weights (Cheviot Ewes)

Level of Nutrition	G.D.E. Consumed	Weight of Ewes			Weight of Lambs
		at 70 days	at term	after lambing	
	lb	*lb*	*lb*	*lb*	*lb*
HIGH PLANE:					
Ewes with singles	108	107	135	116	10.5
Ewes with twins	105	109	140	113	15.5
LOW PLANE:					
Ewes with singles	39	104	98	82	8.3
Ewes with twins	37	109	103	83	10.0

The overall feed conversion was about 10.3 lb G.D.E. for 1 lb lamb in the "high-plane singles" and 6.8 lb G.D.E. for 1 lb lamb in the "high-plane twins". Corresponding figures for the low-plane were 4.7 and 3.7 lb G.D.E. respectively. Although in both instances the twins had been produced more economically than the corresponding singles, it would be wrong to go further and conclude that the low-plane feeding was more economical than the high. The feebleness of the "low-plane" lambs, loss of weight of the ewes and lack of milk all point to the opposite conclusion.

The feed conversion into lamb was less efficient with singles than with twins, because ewes bearing singles ate as much as those with twins, or even a little more, although their single lambs weighed less than the combined weights of twin lambs. The explanation is not apparent. If it is assumed that twin and single foetuses do not differ in the energy needed for development, it appears that certain ewes use energy more economically than others. This may merely be due to less energy being used for maintenance through (say) less exercise being taken, or it may be that there is an adjustment of metabolism towards economy in pregnancy and this is accentuated in a twin pregnancy.

LACTATION

Size of udder is affected by the plane of nutrition during pregnancy, the increase in the last month being about 2 lb in Border Leicester × Cheviot ewes. Udder size at lambing gives an indication of the subsequent milk yield. The yield of milk in a ewe properly fed in the final stages of pregnancy can be more than double that of a ewe given less than a maintenance ration. Furthermore, ewes with twin lambs produce more milk than ewes with single lambs even if fed equally before lambing, because the more thorough milking out by the twins stimulates the gland to respond with a greater secretion.

The question of the S.E. necessary for milk production cannot be

answered until the maintenance requirements of the suckling ewe can be ascertained. There is reason to believe that these are greater than for other adult sheep, and available figures for the latter are therefore not applicable. Wallace has estimated the *total* requirements of the suckling ewe, and gives them in terms of gross digestible energy, which he considers to be more appropriate than S.E., because there is no need to specify what proportion should be allocated to production.

In Suffolks, 0.99 lb G.D.E./lb milk produced was consumed in the first 4 weeks, but 3.38 lb were consumed between the 13th and 16th weeks, the overall average being 1.57 lb G.D.E. For Border Leicester × Cheviots, the corresponding figures were 0.71, 2.20 and 1.07 lb G.D.E. Allowing for the difference in size of the two breeds and assuming (perhaps wrongly) that maintenance needs are the same in lactating as in dry ewes, it is found that when the residual energy is divided by the milk yield, 0.6 lb G.D.E./lb milk is needed in the Border Leicester × Cheviot and 0.8 lb in the Suffolk. However, there were great variations in the conversion efficiencies of the individual ewes and in their yields.

FATTENING

Estimates of the requirement over and above the maintenance for 1 lb liveweight increase have been given, varying from 4 or 4½ lb S.E. (4284 to 4819 kcal of net energy) to 3 lb G.D.E. expressed as starch (5121 kcal of M.E.) which, for the feedingstuffs used, was said to be equivalent to 2½ lb S.E. (2677 kcal of net energy).

The form in which energy-yielding material is absorbed from the rumen is important and further complicates calculations. For production purposes, acetic acid has a lower value than it has for maintenance, and propionic acid is more valuable for production. The amount of propionic is usually proportional to the digested soluble carbohydrates.

PROTEIN REQUIREMENTS

Four ounces digestible crude protein/day is adequate for the later stages of pregnancy in the ewe, and a little more than 2 oz is the minimum for non-pregnant ewes or ewes in early pregnancy. There are few data on the requirements for milk production. Wallace, in the work already mentioned, gave from 0.56 to 0.67 lb protein equivalent/day to Border Leicester × Cheviot ewes for maintenance plus milk production, but this allowance was not based on determined requirements.

MINERALS

For pregnant and lactating ewes 5g Ca (=7g CaO) and 2.5g P (=5.8g P_2O_5)/day are adequate. These quantities do not prevent temporary loss of minerals from the bones during peak lactation, but they allow replenishment to be complete within two months after the end of lactation.

An allowance of 0.1 mg cobalt/day leaves a safety margin of 20 to 30 per cent. There is still disagreement about the copper requirement,

which may alter according to attendant circumstances, but some workers have suggested 5 mg/day.

FINAL REMARKS

Laboratory-determined standards are not likely to be directly applicable to a pastoral animal such as the sheep, but where hand feeding becomes necessary they provide a basis for estimation.

Standards applied to hill sheep are even more hazardous but they may help to evaluate grazing. The only practical means of controlling the nutrition of hill sheep is by improving the grazings and supplying missing minerals but economics will govern the extent of these operations.

Regional Note

Applying Spectrographic Techniques to Agricultural Problems

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DURING the last fifteen to twenty years there have been great strides in our knowledge of the importance of very small quantities of elements such as manganese and boron for the health and growth of plants, and of cobalt and copper for animals. As a result, the demand for methods of determining extremely small amounts of these elements—in parts or fractions of a part per million—has become pressing.

No progress can be made in investigations unless our methods of analysis are accurate down at least to the levels of those trace elements below which plants or animals are damaged. As skill in measurement of smaller and smaller amounts of elements increases, new aspects of plant and animal nutrition are revealed.

One valuable branch of analytical technique is that using the spectrograph. During the past twenty years its agricultural applications have been developed to a high degree of accuracy at the Macaulay Institute in Aberdeen by Dr. R. L. Mitchell and his colleagues.

Scope of the Region's Work

During the last three years, several thousand samples have been examined by spectrographic methods at the Bristol Regional Centre for the whole of the N.A.A.S. Many were received for rapid and accurate determination of magnesium for grassland experiments and horticultural advisory work. Of the more complex quantitative work, determination of cobalt for animal nutrition is probably the most important. Sewage sludges from industrial areas and the plants which have been grown on land dressed with them also provide interest. Among the more unusual investigations have been experimental tomato plants grown at Long Ashton with additions of such elements as nickel, gallium, cobalt and manganese; deposits in water systems; paint strippings on old farm carts which have poisoned cows; and atmospheric pollution deposits on the leaves of plants in cities. In the last, geraniums from a city square in Bristol were found to contain a surprisingly large amount of beryllium.

The two basic principles on which the spectrograph depends are as follows:

1. When the atoms of a particular element are brought to high temperatures by electrical or flame excitation the light emitted is of one or more wave-lengths characteristic of that element alone;
2. When such light is passed through a prism (of glass, quartz or rock-salt) it is split up into a spectrum of all the wave-lengths in successive order. Light of short wave-lengths from ultra-violet into the visible spectrum is bent during its passage through the prism more than light of long wave-length in the red and infra-red.

Practical Aspects

In spectrographic work, the material to be examined can be heated in a flame of coal gas and compressed air or of air and acetylene, or alternatively by a high-tension electrical spark discharge (10,000 volts) or in a direct current arc. The light emitted passes through a very narrow slit—about 0.01 mm wide—on to a prism, usually of quartz, as this allows ultra-violet light to pass more readily than does glass. The prism produces a series of images of the slit corresponding to the various wave-lengths emitted by the material, and these are registered on a photographic plate as a series of short vertical and parallel lines known as a "spectrogram".

The wave-lengths of all the lines in the spectrum of each element have been recorded in books of standard tables and are also available marked on reference photographic prints of spectra. Much of the fundamental work of this kind has been done in the Vatican Laboratories. The number of lines in the spectrum of an element may vary between several thousand for iron and two for boron. With practice, many characteristic lines can be recognized at sight. Identification of the wave-length of any one line can be made certain by photographing

on the same plate the spectrum of the material under examination and the spectrum of a single known element having a large number of lines in its spectrum, all of which have been mapped.

By looking for any spectral line of known wave-length, the presence or absence of any particular element may be determined, and by the degree of blackening of any line on the photographic plate, the amount of that element present may be measured. This process is done by passing a beam of light through the plate and measuring the proportion of light cut off by the black line in the spectrum by means of a "microphotometer", which is a photocell coupled to a galvanometer circuit. The great value of the technique is its power of allowing simultaneous determination of several elements present in very small proportions. As the spectrum lines of all elements present in a sample are recorded on a photographic plate, this can be filed and even years later determinations can possibly be made of an element whose importance was not considered when the plate was first taken.

The Uses of Different-sized Spectrographs

At Bristol there are two quartz spectrographs—the Hilger Medium and Large. The former will record spectrum lines of wave-lengths between 2,220 and 8,000 Ångstrom Units (1 Ångstrom Unit equals one ten-millionth of a millimetre) on a single plate 10 inches long (the eye is sensitive to wave-lengths between 4,000 and 8,000 Å). This instrument is used almost entirely for determining magnesium, and sometimes zinc and manganese, by high-tension spark. About 0.1 ml of plant ash or soil extract is placed in a hollow upper electrode of carbon whose porous base is about 0.6 mm thick. The solution will just seep through the base into the 10,000 volt spark passing between it and the lower pointed carbon rod electrode. The method is simple, rapid and accurate, and has a sensitivity for magnesium of 25 p.p.m. and for manganese of 12.5 p.p.m. in the dry matter, with an accuracy of $\pm$ 2 per cent.

The large spectrograph will cover the same spectrum range of 2,200-8,000 Å on three 10 in. plates, so that much greater dispersion is obtained in the crowded 3,200-4,600 Å range, in which occur the principal lines of the elements having complex spectra, such as cobalt, nickel, molybdenum, chromium, titanium and vanadium. For these elements direct current arc excitation is the most useful method.

It is sometimes believed that spectrographic analysis dispenses with chemical processing of materials for examination. In metallurgical work the metal specimens can themselves be used as electrodes. But complex materials, such as plants and soils contain a wide variety of elements ranging in proportion from large percentages to fractions of a part per million, and frequently there is a large amount of organic matter. Some chemical concentration of trace elements is often necessary, especially when the amount of particular element is near

the level of sensitivity. For example, in the determination of cobalt at a level of 0.02 p.p.m. in plant dry matter, a 500-fold concentration from at least 20g dry matter is desirable for reasonable accuracy.

The chemical concentration process takes about a week and 8 samples are prepared simultaneously on each of which up to 10 different elements may be determined. Photography of the spectrum of the 8 samples on one plate takes about an hour, and determination of the amounts of 10 elements in each sample by micro-photometer will occupy two people a further 1-2 days. With this degree of concentration a wide range of elements may be determined with a high degree of accuracy. For instance, cobalt, chromium, nickel, vanadium and molybdenum can be determined over a range of 0.02-10 p.p.m. in a sample.

Contamination Problems

In the examination of plant material the likelihood of contamination by soil is a serious problem, especially with pasture herbage. The limits of contamination vary for different elements. The table below shows that the effect is not serious for phosphorus, calcium, molybdenum and copper whose average content is much the same in soils and the dry matter of plants. But when the average content in soil is very considerably greater than in plant dry matter, as with cobalt, iron and titanium, even slight contamination can render a determination inaccurate or useless.

Average Element Content in Soils and Plants (p.p.m.)

	P	Ca	Mo	Cu	Co	Fe	Ti
Soil . . .	2,000	20,000	1	30	20	50,000	10,000
Plant (D.M.) .	4,000	20,000	1	10	0.1	100	1
Ratio soil: plant .	0.5	1	1	3	200	500	10,000

The level of titanium in a plant sample is regularly used by spectrographic laboratories as a check on soil contamination of samples. The frequency with which this is found to be greater than 10 p.p.m. is enough to make one wonder how many of the figures of trace element contents quoted in the literature are reliable.

Conclusions

Semi-quantitative examination of plants and soils is being used increasingly when the cause of crop failure is obscure. A very valuable feature of spectrographic analysis is that the photographic plate records in one operation the lines of all, or nearly all, the metallic and semi-metallic elements in a sample, so that examination of the plate may show the presence of an element whose influence had not been considered, but which was important for a diagnosis. It is hoped to develop work on the uptake of various trace elements by different plant species as a foundation for advisory work, and further extension of the range of elements which can be determined accurately in very small quantities will be continued.

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